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# STATUS OF POPULATIONS OF SPOTTED DOLPHIN, STENELLA ATTENUATA, AND SPINNER DOLPHIN, STENELLA LONGIROSTRIS, IN THE EASTERN TROPICAL PACIFIC

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## ABSTRACT

This working paper reports progress on assessing the status of three populations of two species of dolphins of the genus Stenella involved in the purse seine fishery for tuna.

The population of spotted dolphins in 1974 was estimated at 2.3-4.9 million, based on an aerial survey. The estimated annual capacity for increase (total births minus natural deaths) is 1.4-4.0%. The estimated annual rate of observed incidental mortality in the fishery in 1974 is 1.6-4.2%. Comparison of the incidental mortality rate with the capacity for increase leads to the conclusion that the kill in 1974 of 79,900-97,300 spotted dolphins is at or near the production available after natural mortality. A component of incidental mortality may be unmeasured, however. The number killed incidentally was higher in earlier years (estimated for 1971-1973), and the spotted dolphin population is estimated to have declined. The amount of decline has not yet been determined.

The population of a second dolphin involved in the tuna fishery, the eastern spinner dolphin, was estimated at 0.4-1.1 million. The capacity for increase has not been estimated, but if it is about the same as that of the spotted dolphin (1.4-4.0%), then the predicted incidental kill in 1974 of 26,500-32,400 (2.4-8.1% of the population) will probably cause the population to decrease.

The impact of the tuna fishery on the whitebelly spinner population has not yet been assessed.

Several recommendations are made for further research.



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# СОСТОЯНИЕ ПОПУЛЯЦИЙ ПЯТНИСТОГО ДЕЛЬФИНА ( STENELLA ATTENUATA ) И ВЕРТЯЩЕГОСЯ ПРОДЕЛЬФИНА ( STENELLA LONGIROSTRIS) В ВОСТОЧНОЙ ТРОПИЧЕСКОЙ ЧАСТИ ТИХОГО ОКЕАНА.

УИЛЬЯМ Ф.ПЕРРИН, ТИМ Д.СМИТ, ГАРИ Т.САКАГАВА

## АВТОРЕФЕРАТ

Настоящая статья сообщает об успехах оценки состояния трех популяций двух видов дельфинов рода STENELLA ,отлавливаемых кошельковым неводом вместе с тунцом.

Популяция пятнистых дельфинов в 1974 году была оценена,на основе данных авиаразведки, в 2.3 - 4.9 миллионов экземпляров.

Оцениваемая ежегодная способность роста численности ( общая рождаемость минус естественная смертность ) составляет 1.4 - 4.0%.

Ежегодный размер наблюдаемой случайной смертности в сетях по оценке 1974 года составляет 1.6 - 4.2%.

Сравнение степени случайной смертности со способностью к увеличению численности приводит к выводу,что гибель в 1974 году 79.900 - 97.300 экземпляров пятнистых дельфинов приблизительно равна числу естественной смертности.Однако число случайной смертности трудно определить.

Число случайной смертности было выше в предыдущие годы ( оценка 1971-1973гг. ) и популяция пятнистого дельфина сократилась. Количественно уменьшение численности не было еще определено.

Популяция второго дельфина,восточного вертящегося продельфина отлавливаемого рыболовными сетями вместе с тунцом,была определена в 0.4 - 1.1 миллионов экземпляров.

Способность к увеличению численности не была оценена,но если она такая же как у пятнистого дельфина ( 1.4 - 4.0% ) ,то в этом случае,предсказываемая случайная гибель в 1974 году 26.500-32.400 голов ( 2.4 - 8.1% от популяции ) будет,вероятно,причиной уменьшения популяции.

Ущерб,наносимый популяции белобрюхого вертящегося продельфина связанный с отловом тунца не был еще определен.

Сделаны некоторые рекомендации для будущего исследования.

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# I. INTRODUCTION

Tuna fishermen in the eastern tropical Pacific kill dolphins incidentally in the course of their seining operations (Perrin, 1969; NOAA, 1972). About 2 years ago, we set out to assess the impact of this on the dolphin populations.

This report is basically a very brief summary of portions of a draft document entitled "The porpoise-tuna problem: Review of research progress" (draft title), which was written at this laboratory in August-September and was made available to the public by the National Marine Fisheries Service (NMFS) in October 1974. There have since been adjustments and corrections to the material in that report. This reflects mainly the fact that we are working with preliminary 1974 estimates that change as the year progresses. The draft is still under review, and more adjustments and corrections can be expected before the report appears in its final form.

This paper reports, in general terms, what we did and what the results were. The details of the data and analyses are in the draft report itself.

# II. METHODS

## A. General Approach

Our basic goal in assessing the impact of the fishery was to answer the question, are the populations declining? We have done this by comparing estimated exploitation rate (number incidentally killed ÷ population size) with capacity for increase (in simplistic terms, birth rate minus natural death rate). The inputs into these two basic characteristics are laid out in the flow diagram (Figure 1). Incidental kill was estimated from the landings of yellowfin tuna from dolphin schools, the number of net sets, and an estimate of average kill per set. Population size was estimated from density estimates extrapolated to known range. Capacity for increase was calculated from estimates of reproductive parameters in the exploited eastern Pacific population and of natural mortality rates in the relatively unexploited western Pacific population.

Two forms of Stenella attenuata and three of S. longirostris exist in the eastern Pacific. The distributions and bases for separation of these forms and their relative importances in the fishery have been described previously (Perrin, 1974). We have concentrated on assessing the status of the most important form, the offshore spotted dolphin (Table 1). We also gave major attention to the eastern spinner dolphin, but have so far estimated only exploitation rate and not capacity for increase. For the third major form, the whitebelly spinner, we have thus far estimated only the incidental kill.

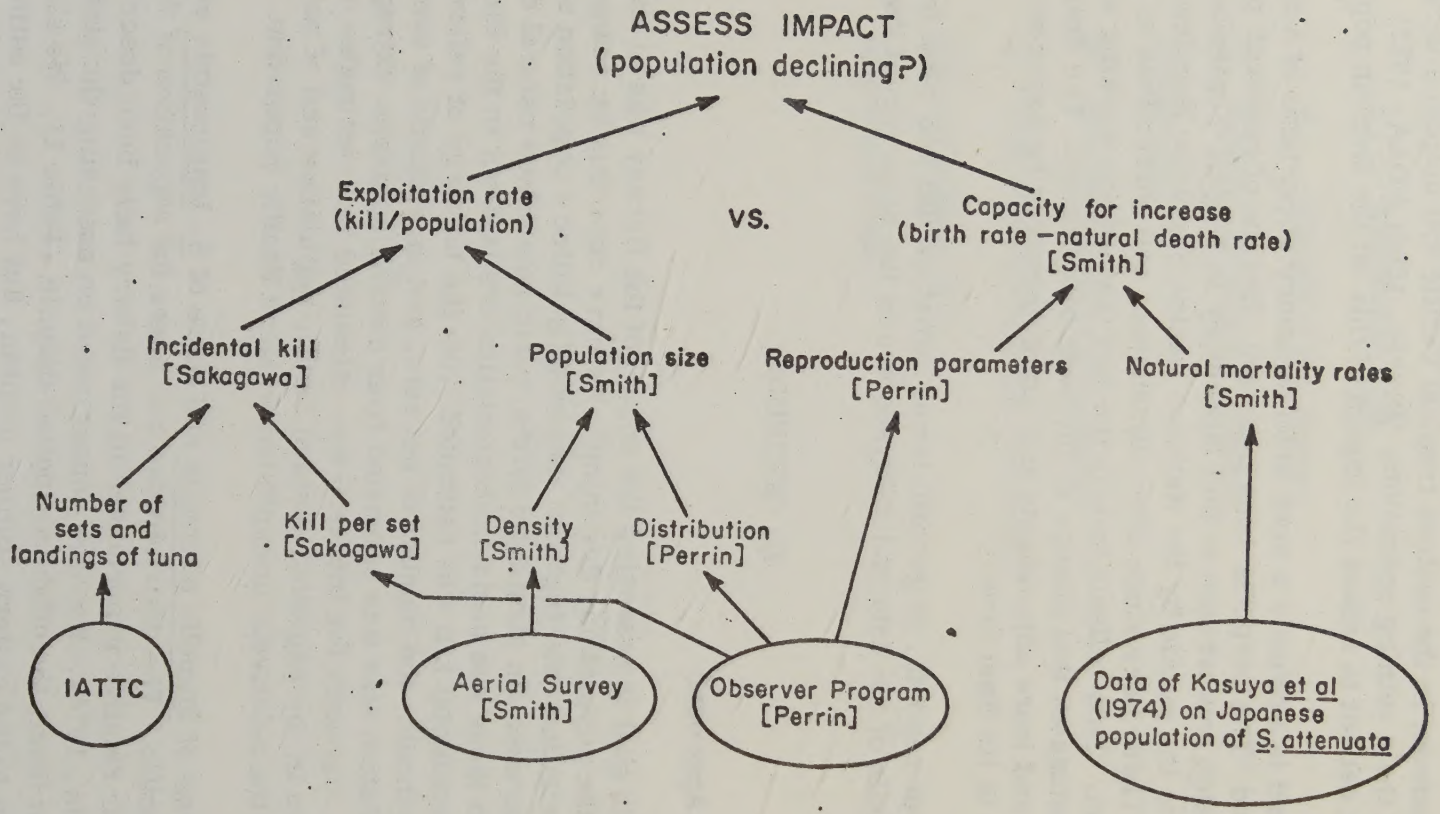


Figure 1. Flow diagram for assessing impact of incidental fishing mortality on dolphin populations. Major data sources circled. Names in brackets indicate authors' responsibilities for field programs and major analyses.

Table 1. Populations of spotted and spinner dolphins in the eastern Pacific, and scope of analyses reported in this working paper.

| Population | Involvement in fishery[1] | | | Assessment of status[2] | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Exploitation rate | | Capacity for increase | | |
| | Major | Minor? | Negligible | Incidental kill | Population size | Reproductive parameters | Natural mortality | Impact assessed |
| 1. Coastal spotted dolphin (S. attenuata subspecies) | | X | | | | | | |
| 2. Offshore spotted dolphin (S. attenuata subspecies) | X | | | X | X | X | X | X |
| 3. Costa Rican spinner dolphin (S. longirostris subspecies) | | | X | | | | | |
| 4. Eastern spinner dolphin (S. longirostris subspecies) | X | | | X | X | | | X |
| 5. Whitebelly spinner dolphin (S. longirostris subspecies) | X | | | X | | | | |

[1] Major = 1,000 killed incidentally; minor = 100's killed; negligible = 10's or fewer killed.

[2] X = estimates made in present study.

B. Major Sources of Data

Our major sources of raw data were the Inter-American Tropical Tuna Commission (IATTC), an aerial survey, and the tunaboat Observer Program.

1. IATTC

The IATTC provided data on numbers of purse seine sets on dolphin schools by vessel class for the U.S. fleet and on landings of tuna caught with dolphins by all nations.

2. Aerial Survey

An aerial survey conducted in January-February 1974, provided data on density of dolphin schools in the eastern tropical Pacific. Approximately 12,000 track miles were flown in a specially modified Gruman Goose, at an average altitude of about 1,500 feet (Figure 2). Two observers scanned ahead and to the side. The track lines were selected before the survey, independently of any knowledge of the density of dolphin schools. Range capabilities of the aircraft and locations of suitable airports constrained the choice of track lines.

3. Observer Program

We have had observers on purse seiners every year since 1971. Among other things, the observers have collected data on numbers of dolphins killed, on distribution, and on sex, age, and reproductive condition of a sample of the animals killed. We had observers on 5 cruises in 1971, 12 in 1972, 23 in 1973, and about 40 in 1974. We have also collected data during several cruises chartered to NMFS for gear research.

C. Estimating Incidental Kill

Our basic approach in estimating the incidental kill was to extrapolate from estimates of kill per net set in our observer sample to the entire fishery based on data from the IATTC (Figure 3). We were faced with several problems in this approach: 1) the structure of our sample may or may not be representative of the U.S. fleet, 2) we did not sample the non-U.S. fleet, and 3) the Observer Program was effectively limited to the Commission Yellowfin Regulatory Area (CYRA)--Figure 4--and did not sample the "outside the line" area to the west where roughly 1/3 of the tuna caught with dolphins is taken.

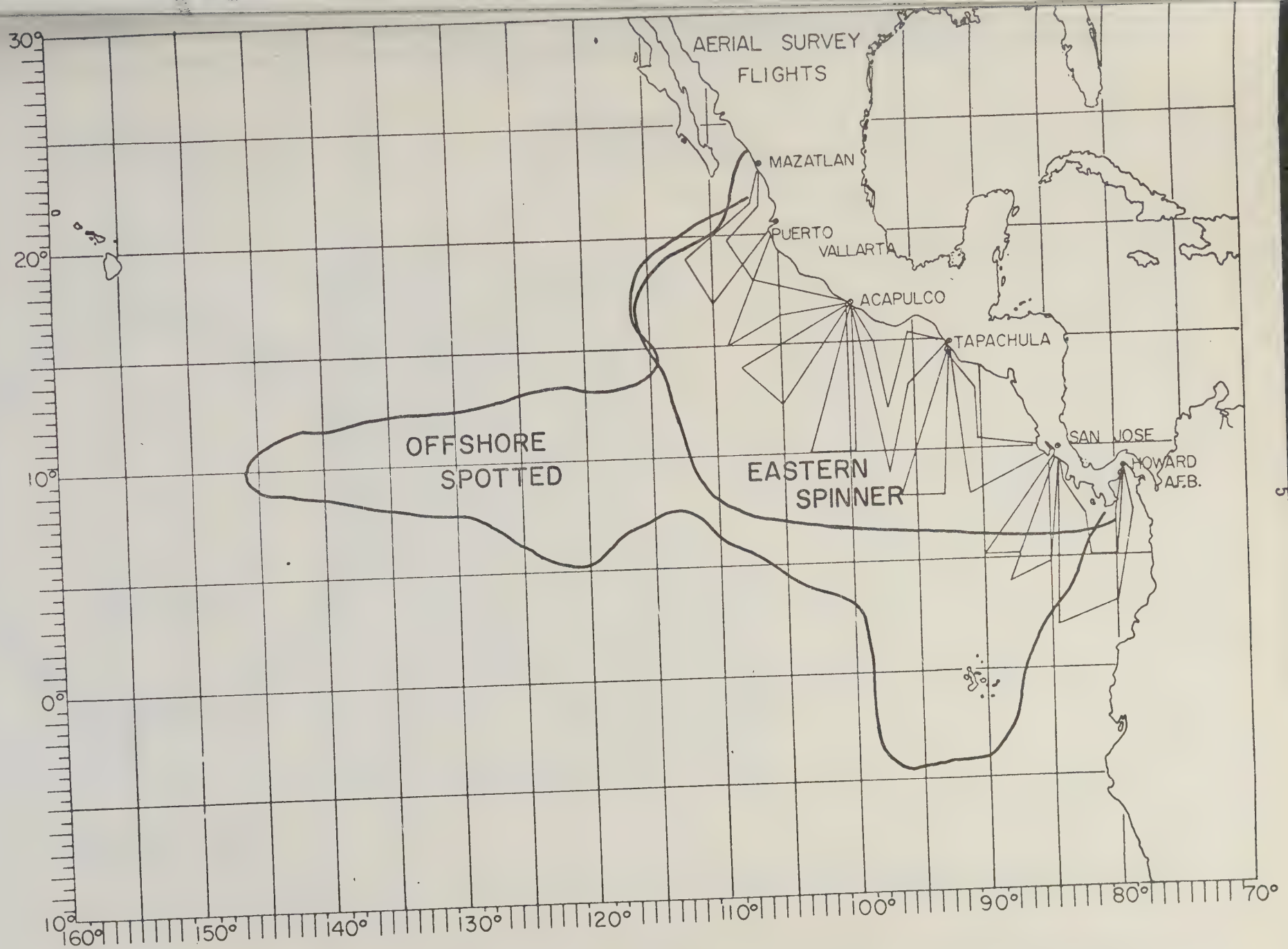


Figure 2. Location of track lines on the aerial survey in early 1974. Historical ranges of offshore spotted dolphin and eastern spinner dolphin from Perrin (1974).

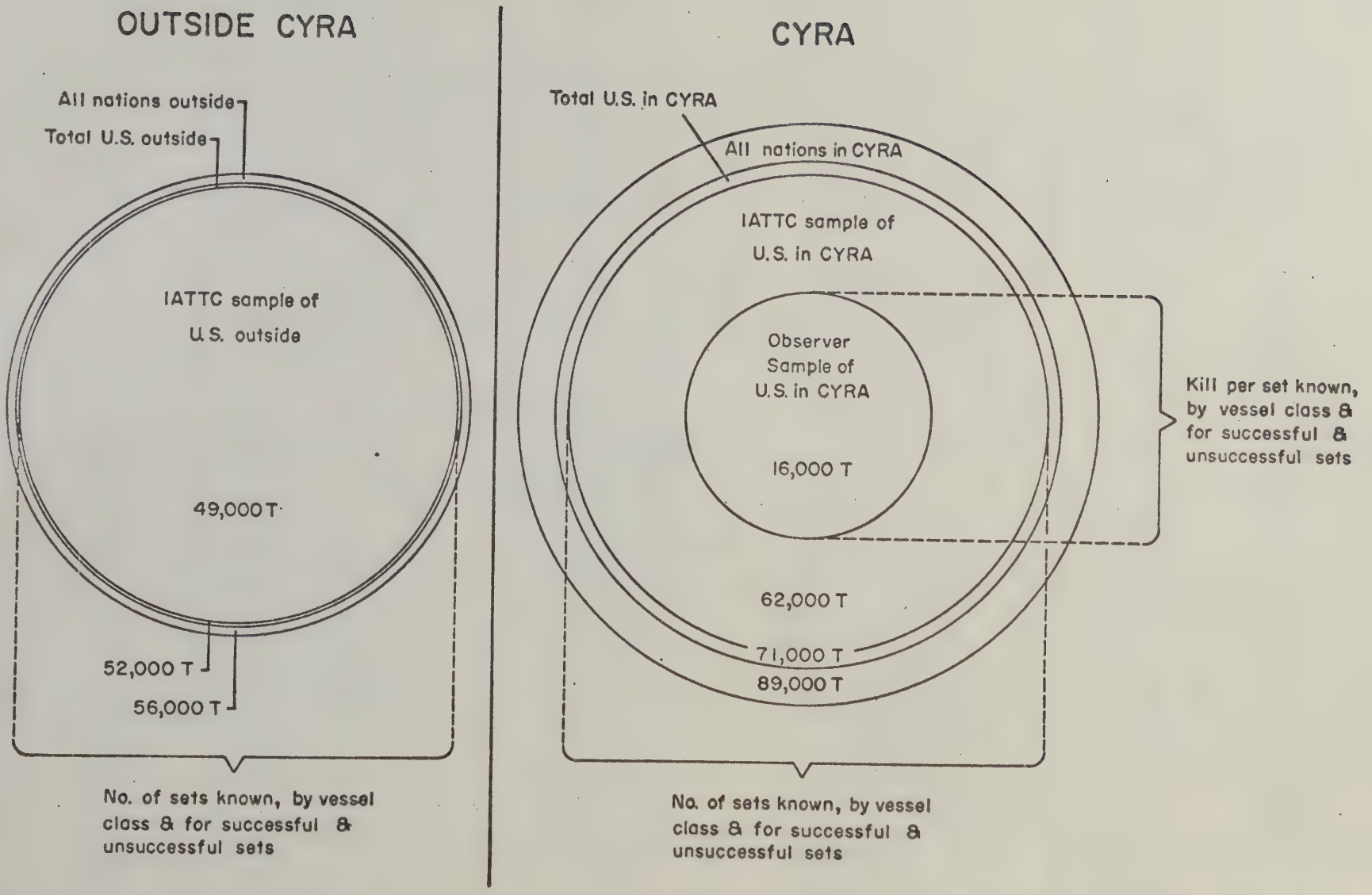


Figure 3. Samples used to estimate incidental kill of dolphins in the yellowfin tuna purse seine fishery in the eastern tropical Pacific. Areas of circles are proportional to landings of yellowfin tuna taken in set

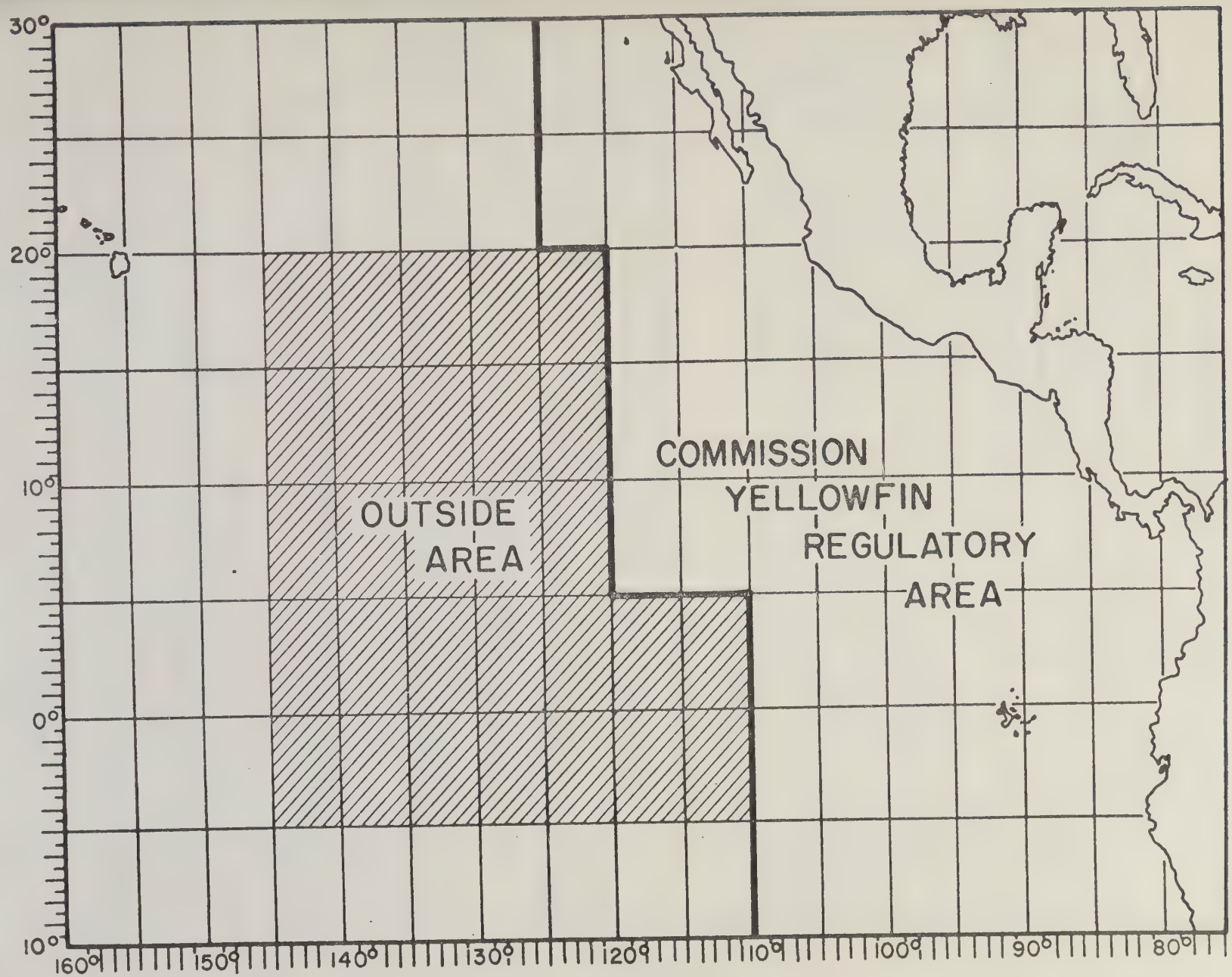


Figure 4. The major part of the Inter-American Tropical Tuna Commission regulatory area (CYRA) is shown above. Principal zone of "outside" fishing is also indicated.

1. Adjusting for Structure of the Observer Sample

In looking at our earlier data, we found that dolphin kill per net set is correlated with characteristics of the vessel, mainly size. Beginning in 1974 the tunaboats have been required by law to carry observers when requested, so we have been able this year to design our sample to have about the same structure as the fleet in terms of size of vessels. In the earlier years, however, carrying an observer was voluntary, and we know that some of those samples did not well represent the fleet. In 1971, for example, the sample contained proportionately more small, old vessels than did the fleet. Detailed descriptions of the samples and the fleet are in the draft progress report. We attempted to correct for this sample bias by extrapolating on the basis of kill per set for size-age classes of vessels. We used eight strata ranging from 101-200 tons capacity to 1,200+ tons. We also found dolphin kill is correlated with whether or not the net set is successful in capturing yellowfin tuna, so we stratified our extrapolating procedure also on the basis of success or non-success of the set. A successful set was defined as one in which at least 1/4 ton of yellowfin tuna was taken.

2. Estimating Non-U.S. Kill

Since we have very few kill-per-set data and no data on sets by vessel class for the non-U.S. fleet, we simply assumed that overall kill per set is the same as for the U.S. fleet and extrapolated from the U.S. sample on the basis of tons of tuna taken with dolphins.

3. Estimating Kill Outside the CYRA

Essentially no observer data were available from outside the CYRA, so we assumed for the purpose of our estimates that kill per set is the same as in the CYRA.

With this approach, we made four estimates of incidental kill (of all species):

(1) U.S. kill in the CYRA
(2) Kill by all nations in the CYRA
(3) U.S. kill outside the CYRA
(4) Kill by all nations outside the CYRA,

using the model

$$\hat{K}_l = \hat{C}_g \left( \sum_{i=1}^{8} \sum_{j=1}^{2} N_{ij} k_{ij} \right),$$

where $\hat{K}$ = estimated kill

$k_{ij}$ = kill per set in observer sample stratum ij

$N_{ij}$ = number of net sets in IATTC sample of U.S. landings of yellowfin from dolphins

i = vessel size class

j = type-of-set class (successful or unsuccessful)

$\hat{C}_g$ = extrapolation factor to account for landings not in IATTC sample of U.S. landings

g = estimate [(1) - (4) above].

An approximate estimate of variance for $\hat{K}$ is

$$\text{var}(\hat{K}) = C_g^2 [\Sigma\Sigma N_{ij}^2 \text{ var}(k_{ij})],$$

and the approximate 95% confidence interval for $\hat{K}$ is

$$\hat{K} \pm 2\sqrt{\text{var}(\hat{K})}.$$

We do not have the information on landings for 1974 from outside the CYRA as yet, so we assumed that they would be about as large in relation to the CYRA landings as they were last year (1973), and derived estimates of mortality outside the CYRA on that basis.

We broke down the total estimates (CYRA + outside) to estimates by species based on the species compositions of samples examined in the observer program. The estimates for the spinner dolphin for 1974 were prorated to the eastern and whitebelly populations based on the ranges of the forms and on the relative percentages of sets in the observer sample known to have been made on each.

For 1974, we made two sets of estimates, a set of "low" estimates based on an assumed total catch of 175,000 tons of yellowfin tuna for the season and a low percentage (40%) of tuna taken with dolphins by non-U.S. vessels, and a set of "high" estimates based on an assumed total catch of 195,000 tons and a high percentage (56%) of yellowfin tuna taken with dolphins by non-U.S. vessels.

D. Estimating Population Size

We estimated density of schools of the offshore spotted dolphin and eastern spinner dolphin from data collected in the aerial survey. The basic analytical tool used was line transect theory. When a school was sighted, the perpendicular distance from the track line was estimated. The manner in which the number of sightings declined with distance from the track line was used to determine how much area was effectively searched. Four basic conditions must be met in this approach:

(1) schools are distributed at random,
(2) transects are placed at random,
(3) probability of sighting a school decreases exponentially with distance from the track line, and
(4) probability of seeing a school directly on the track line is 1.0.

Making these assumptions, we estimated density as

$$\hat{D} = (n - 1)/2L\bar{Y},$$

where $n$ = number of schools sighted,

$L$ = total track miles surveyed, and

$\bar{Y}$ = average perpendicular sighting distance, in this case about 1 mile.

Variance of the density can be estimated as

$$V(\hat{D}) = \frac{\hat{D}^2}{n}\left(1 + \frac{n}{n-2} - \frac{n}{\hat{D}A}\right).$$

We prorated the overall density estimates into estimates for each stock based on the proportion of the total sightings which were of that stock. We also estimated separately for mixed schools, because size of single-stock components in mixed schools is different than size of single-stock schools. We estimated separately for pure spotted schools, pure eastern spinner schools, spotted in mixed schools, and eastern spinner in mixed schools.

We then estimated the total number of schools of each stock and school type by extrapolating the density to the known historical range (Perrin, 1974). This makes the assumption that density of schools in the area sampled is representative of the entire historical range. Variance of the estimate of total schools can be calculated as

$$V(\hat{S}_i) = A_i^2 V(\hat{D}_i),$$

where $\hat{S}_i$ = number of schools or school components of stock-school type i, and

$A_i$ = area inhabited by schools of stock-school type.

Then, using estimates of average school size (or single-stock component size) from the Observer Program, we estimated the total number of dolphins for each stock-school component type as

$$\hat{N}_i = \hat{C}_i \hat{S}_i,$$

where $\hat{N}_i$ = total number of dolphins in component i, and

$\hat{C}_i$ = average size of schools or single-stock school components.

Variance can be calculated as

$$V(\hat{N}_i) = V(\hat{C}_i)\hat{S}_i^2 + V(\hat{S}_i)\hat{C}_i + V(\hat{C}_i)\,V(\hat{S}_i).$$

We then added the single-stock school and mixed-stock school components to obtain an estimate for each of the two stocks:

$$\hat{P}_j = \Sigma \hat{N}_i,$$

where $\hat{P}_j$ = population of stock j.

The variances of $N_i$ are additive. We expressed the population estimates as interval estimates, which were ± 2 standard deviations from the point estimates. This interval should contain the true value at least 75% of the time.

We used average school size estimates from the Observer Program, because the sample size from the aerial survey was very small and if used would have greatly increased the variance of the population estimate. This was justified because the aerial estimates did not differ significantly from the Observer Program estimates.

The major criticisms that can be made of the population estimates follow.

(1) Density of schools may not be the same throughout the ranges. There may be areas of higher or lower density in the unsurveyed offshore parts of the ranges. This could bias the estimates either way.

(2) The actual range at one point in time is probably smaller than the historical range. There may be seasonal migrations and year-to-year changes in occupied range caused by large-scale environmental fluctuations, e.g., the El Niño condition in 1973. This would bias the estimates upward.

(3) The assumption that all schools directly on the track line were seen may not be valid. If some schools were missed, this would bias the estimate downward.

E. Estimating Reproductive Parameters

The samples, methods, and analyses used in the studies of the life history of S. attenuata are described in detail in a manuscript that we are preparing for publication (Perrin, Coe, and Zweifel, MS). The studies were based on about 10,000 specimens collected in the Observer Program. The primary inputs into the status assessment are the estimates of age-specific pregnancy rate. We estimated age by looking at growth zones (layers) in the teeth. There are two sources of uncertainty in the pregnancy rate estimates. One has to do with the number of growth zones deposited yearly in the teeth, and the other concerns the rate of change of pregnancy rate with age. We could not satisfactorily resolve either of these uncertainties,

satisfactorily resolve either of these uncertainties, so the inputs into the assessment model were in terms of alternatives, i.e., one layer or two tooth layers accumulated yearly in adults, and pregnancy rate being either constant, decreasing "slowly", or decreasing "rapidly" with age (defined below).

F. Estimating Capacity for Increase

The capacity for increase is basically the difference between the gross annual production and the average annual natural mortality. It changes as the environment of the population changes. Change in size of a population itself can cause its capacity for increase to change. It is to be expected that capacity for increase increases when a population is exploited.

The basic approach used to estimate capacity for increase is based on Leslie matrix models. The basic inputs are age-specific pregnancy rates and age-specific natural mortality rates. These rates are combined in a matrix which can be used to project the population forward in time. This matrix can be analyzed to determine the capacity for increase implied by the natality and mortality rates. The model equation of interest here is

$$\underline{M}\vec{N} = \lambda\vec{N},$$

where $\underline{M}$ is the Leslie matrix describing the western Pacific stock,

$N$ is the age structure vector, and

$\lambda$ (lambda) is a scalar constant indicating the annual change in the population size with the life history parameters incorporated in the Leslie matrix $\underline{M}$.

If $\lambda$ is equal to 1.0, the population neither increases nor decreases in size. If it is less than or greater than 1.0, the population decreases or increases, respectively. The capacity for increase is defined as $(\lambda - 1/\lambda)$.

We do not have estimates of natural mortality rates from the fishery because we cannot separate natural mortality from incidental mortality. Biological data are available for an unexploited spotted dolphin population near Japan (Kasuya, et al., 1974). These data can be used to derive natural mortality rates to use as first approximations for the rates for the eastern Pacific stock. Kasuya, et al. did not give estimates of the mortality rates of immature animals more than one year old. They did give estimates for the mortality rate of first year calves. These estimates are very low and are not consonant with an equilibrium population, given the calving intervals, which are more directly calculated and seem reasonable.

Therefore, we estimated new mortality rates for calves and rates for older immature animals indirectly. If the adult mortality rates and the reproductive rates estimated for this stock hold, and if the population is in equilibrium, certain values of mortality rates for calves and older immature spotted porpoise are implied. These implied values are determined as those which satisfy the model equation when = 1.0.

We then determined the capacity for increase for the eastern Pacific stock by combining in one matrix the mortality schedule estimated for the western Pacific stock and the reproductive schedule estimated for the eastern Pacific stock. Analysis of this model yielded the desired estimates of capacity for increase. A basic assumption is that the reproductive rates have increased in the eastern Pacific stock due to a decrease in stock size, while the natural mortality rates have not changed.

These estimates of capacity for increase can be directly compared to the annual incidental exploitation rate determined as the ratio of the estimate of numbers killed to the estimated population size. If the incidental exploitation rate is less than the capacity for increase, the population should increase; and if it is greater than the capacity for increase, the population should decrease.

It should be noted that this analysis assumes that the incidental mortality occurs equally over all age classes. It also assumes that the population age structure has had time to achieve a stable form. Both of these assumptions, especially the latter, need to be examined further.

# III. RESULTS

## A. Offshore Spotted Dolphin

### 1. Incidental Kill

The estimated incidental kill has declined each year since 1972 (Table 2), to about 80,000-100,000 in 1974, of which about 3/4 is ascribable to the U.S. fleet.

We stress the fact that these estimates must be considered minimal estimates for several reasons, to wit:

(1) Only animals known to be dead were counted; we have made no attempt to take into account the injured animals, some of which can be presumed to have died after release from the net.

(2) Kill data were gathered only from U.S. vessels, which probably perform better in preventing incidental mortality than do most non-U.S. seiners. The non-U.S. fleets contain many small, old vessels that were formerly in the U.S. fleet.

(3) Some observer effect can be presumed. With the stratified approach, the problem of representation of the fleet in terms of vessel characteristics is solved, but kill rates may be higher on cruises not accompanied by observers than on cruises with observers.

### 2. Population Size

We saw 54 schools containing offshore spotted dolphins along the 12,000 track miles of the aerial survey. This extrapolates to 2.3-4.9 million offshore spotted dolphins in the eastern Pacific.

### 3. Capacity for Increase

The estimate of capacity for increase depends on the choice of alternative assumptions about life history. For tooth layering, the basic options are one or two layers per year. For reproduction, the basic

Table 2. Estimated incidental kills of spotted and spinner dolphins in the eastern tropical Pacific, 1971-1974, in thousands. Estimates for 1974 are preliminary.

| Year | Spotted dolphin[1] | | | Spinner dolphin | | |
|---|---|---|---|---|---|---|
| | U.S. | Non-U.S. | Total | U.S. | Non-U.S. | Total |
| 1971 | 179.7 | 4.6 | 184.3 | 126.4 | 3.2 | 129.6 |
| 1972 | 237.6 | 32.7 | 270.3 | 56.7 | 7.8 | 64.5 |
| 1973 | 90.6 | 17.1 | 107.7 | 56.9 | 10.7 | 67.6 |
| 1974[2] | | | | | | |
| (low) | 67.2 | 12.7 | 79.9 | 38.1 | 7.2 | 45.3 (26.5 eastern, 18.8 whitebelly) |
| (high) | 74.4 | 22.9 | 97.3 | 42.2 | 13.0 | 55.2 (32.4 eastern, 22.8 whitebelly) |

[1]Estimates are for two populations: (1) coastal spotted and (2) offshore spotted. All of this kill is assigned to the offshore spotted dolphin population, although some coastal spotted dolphin are involved.

[2]The 1974 tuna fishery is in progress and fishery data from inside the CYRA only are available. Estimates are therefore preliminary and based on data for the non-regulated season and on an assumed year's catch of 175,000 to 195,000 short tons for the CYRA. The low estimates assume a low percentage (40%) of yellowfin tuna taken with dolphin by foreign vessels. The high estimates assume that a high percentage, i.e., 56% as occurred in 1972, of yellowfin tuna are taken with dolphin by foreign vessels.

options are the frequency of reproduction after sexual maturity being constant with age or declining with age. Consideration of all the reasonable alternatives results in a range of estimates of capacity for increase of -2.5% to +6.6% per year as shown in Table 3.

None of the alternatives shown in Table 3 can be eliminated with certainty. However, there is some basis for choice. One tooth layer deposited per year has been suggested for the western Pacific population of S. attenuata by Kasuya et al. (1974). One layer per year has also been suggested for other closely related delphinids, including S. coeruleoalba (Kasuya, 1972) and Tursiops truncatus (Sergeant, Caldwell, and Caldwell, 1973). Two tooth layers have been suggested for Delphinapterus leucas (Sergeant, 1973), but this form is less closely related to Stenella. Thus, it is reasonable to assume the tooth layering for the spotted dolphin is basically one per year.

The estimates of frequency of reproduction with age are based on the relationship between pregnancy rates and numbers of tooth layers. The observed data suggest a decrease in pregnancy rate from 0.6 at 7 layers to 0.4 at 12 layers (Perrin et al., MS). This is termed "decreasing rapidly" in Table 3. The determination of numbers of layers is difficult after the pulp cavity closes at about 12 layers. If the pregnancy rate observed for 12-layer animals is actually the pregnancy rate for all animals age 12 layers or older, then pregnancy rate declines more slowly with age. This is termed "decreasing slowly" in Table 3. Because of the difficulty in reading layers for older animals, it is most reasonable to assume that the reproduction rate either declines slowly with age or is constant with age.

With these assumptions of 1) one tooth layer per year and 2) either constant or slowly decreasing reproductive rates with age, the range of estimates of capacity for increase is 1.4-4.0% (Table 3). Although the other hypotheses cannot be completely ruled out and must be allowed as possibilities, this range represents the most likely values given present information.

4. Impact of the Fishery

Dividing the incidental kill for 1974 of 79,900-97,300 by the population size of 2.3-4.9 million yields an estimate of annual incidental exploitation rate of 1.6-4.2%. Comparison of this with the probable capacity of increase of 1.4-4.0% leads to the conclusion that the known incidental kill is probably at or near the surplus production and that the offshore spotted population size will probably not change in 1974. This, of course, is taking into account only the measured kill. It is to be assumed that if all kill were measured, including that caused by the unmonitored factors discussed above, the overlap of incidental kill rate with capacity for increase would be less. This factor may be an

Table 3. Possible capacity for increase for Stenella attenuata as percent of current population size under alternative assumptions.

| Reproductive rate with age | Numbers of tooth layers per year | |
|---|---|---|
| | One | Two |
| Constant | 2.3 - 4.0 | 2.9 - 6.6 |
| Decreasing | | |
| Rapidly | -1.0 - +0.3 | -2.5 - -0.8 |
| Slowly | 1.4 - 2.6 | 1.8 - 3.3 |

important one. In our impact model for the spotted dolphin, for example, we have been working with an average annual total mortality rate on the order of 15% (assumed natural mortality plus known incidental mortality). However, we have some independent estimates of total mortality in the first year, based on structure of the sampled kill, that range from 35-70%. This suggests that there may be unmeasured incidental mortality of calves.

We have done some back extrapolations on the basis of earlier fishing activity and kill rates to examine the question of whether or not the population is at its original size. The balance of evidence suggests that there has been a decline. We don't know yet how great it has been. These analyses are still being revised and refined.

B. Eastern Spinner Dolphin

1. Incidental Kill

The estimated total kill of spinner dolphins has declined about 1/4 since 1972, to about 44,000-55,000 in 1974 (Table 2). Of these, an estimated 26,500-32,400 will be eastern spinners.

2. Population Size

We made 36 sightings of eastern spinner schools on the aerial survey. This extrapolates to a population of 0.4-1.1 million animals.

3. Impact of the Fishery

Dividing the incidental kill by the population size yields an estimate of annual measured incidental kill rate of 2.4-8.1%. We have no estimate of capacity for increase. If, in the absence of such an estimate, we speculate that the capacity for increase is about the same as for the spotted dolphin, or about 1.4-4.0%, then the estimate of incidental kill would suggest that the eastern spinner population will decrease in size during 1974.

C. Whitebelly Spinner Dolphin

For the whitebelly spinner, we know only that about 18,800-22,800 will probably be killed incidentally in 1974. We as yet have no estimates of population size or capacity for increase.

# IV. DISCUSSION

## A. Shortcomings of the Studies

We have established that the aerial survey approach is feasible, but our population estimates are weak because they involve extrapolation to large portions of the ranges that were not surveyed. Also, the estimates based on aerial surveys have high variability due to small sample size. We need an estimate for the whitebelly spinner population. We have not yet surveyed on a large enough scale.

We still have the problem of calibration of growth zones in the teeth. Until this question is settled, the estimates of reproductive parameters are only provisional. We do not have any estimates yet for the spinner dolphins, of course.

The estimates of measured incidental kill may be inaccurate because of the lack of data for the area outside the CYRA and for the non-U.S. fleet. We also need to get a handle on the now unmeasured kill.

## B. Recommendations for Research

The following need to be done in order to adequately assess the status of the stocks:

(1) Monitor the sizes of all dolphin stocks involved in the tuna fishery, using expanded surveys that adequately cover the geographical range of each stock. Population estimates should be made over a period of years, so that the existence or absence of trends can be firmly established. Additional sources of potential information, such as IATTC data, need to be explored to assist in establishing the history of the status of the stocks.

(2) Continue to monitor the incidental kill of dolphins in the tuna fishery, through a continued observer program or some other scheme. Kill should be estimated stock-by-stock. An attempt should be made to measure possible effects on dolphin stocks in addition to the presently measured direct incidental mortality.

(3) Estimate life history parameters for the several spinner dolphin and whitebelly dolphin stocks and resolve the question of tooth-layer deposition rate in the spotted dolphin, which is central to estimating parameters.

(4) Increase the interchange of relevant scientific information at the international level. This should include cooperation among the tuna seining nations in developing programs and techniques for data collections and analysis. A specific example of another potentially valuable area of scientific interchange would be a thorough comparison of the status and history of exploited dolphin populations in the eastern Pacific with the exploited population of whitebelly dolphins in the Black Sea. This would require analysis of much Soviet research information not now readily available.

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